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COMPLETE SPECIFICATION.

Improvements in or relating to a Starter Device for High Speed Internal Combustion Engines.

We, THE GARRETT CORPORATION, a Corporation organised under the laws of the State of California, United States of America, of 9851, Sepulveda Boulevard, Los Angeles, California, United States of America (Assignees of HOMER J. WOOD), do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates generally to the power plant art and more particularly to a pneumatic starter device adapted for use in starting the operation of a power plant, especially one of an aircraft type.

The present invention provides a starter device for a high speed internal combustion engine having a shaft, comprising: a housing adapted to be detachably connected to the engine; a drive shaft rotatably supported to the housing and adapted to be operatively connected to the shaft of the engine; a turbine in said housing having an air driven wheel; and transmission means interconnecting said wheel and said drive shaft, said transmission being adapted to partially or completely interrupt the transmission of power to the drive shaft in response to the occurrence of an overload condition.

Among the many acute problems in the operation of modern aircraft power plants is the accomplishment of what erroneously appears to be a relatively simple operation, namely, that of starting some types of internal combustion engines, and especially turbo-jet and turbo-propeller engines. The problem of starting reciprocating engines is a relatively simple one, and many starter devices have been developed which are suitable for the purpose. The problem of starting such engines is simplified by the fact that the reciprocating engine starts at a relatively low cranking speed and, under normal conditions, a few revolutions are sufficient to start the firing of the engine. On the other hand, the turbine engine must be rotated at a relatively high speed before it is capable of taking over under its own power. It is thus apparent that it is necessary to overcome initial inertia of the rotatable parts, accelerate them to the speed necessary to fire, and then assist the engine in further accelerating to approximately twice this speed to permit the turbine to satisfactorily accelerate itself from that point to operating speed, the successful completion of this starting operation within a practical period of time requiring the expenditure of much more energy than is necessary in starting reciprocating engines. Moreover, in the case of turbo-jet and turbo-propeller engines, to insure efficient, dependable performance, starting power desirably should be available under all conditions and from a source capable of providing an unlimited number of starts without the need for additional equipment or supplies. As a further prerequisite, when this source of power is to be airborne it must be very light in weight and occupy a minimum of space in the aircraft.

Various systems are now in use or being studied with a view toward accomplishing satisfactory starting of turbine engines under all conditions, these systems being classified generally as:

(a) Electric
(b) A small auxiliary reciprocating engine
(c) A small steam turbine
(d) Solid propellant
(e) Pneumatic
(f) Hydraulic

Of the six systems mentioned above, the electric and pneumatic are considered most practical and of the two last-named systems, the pneumatic system is believed

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more feasible from the engineering standpoint, the reasons for such conclusion being outlined hereinafter.

Systems (*b*), (*c*), (*d*), and (*f*) present additional supply problems, maintenance problems, or both. The light weight reciprocating engine presents its own starting and maintenance problems especially at low ambient temperatures. A steam turbine system must necessarily include boilers, piping, etc., and requires additional maintenance and attention.

Solid propellants have been proposed for the purpose of starting power plants and while such means have been reasonably successful in connection with certain small reciprocating engines, when they are employed for starting turbo-jet engines their size is prohibitive. In addition, the solid propellant is costly and each charge delivers a single start and the large bulk and weight of each individual charge sharply limits the number that can be carried aboard the aircraft.

Hydraulic starter systems are relatively heavy, subject to leaks with their ever-present fire hazard, and require much plumbing capable of conveying the hydraulic medium under high pressure. In addition, such systems must include hydraulic pumps driven by some source of power in the form of a small gas turbine or reciprocating engine. A tank must be provided for the hydraulic liquid and the use of a cooler is necessary for maintaining the temperature of the liquid within practical operating limits. The combining of all these components results in a heavy, bulky, and complicated system which requires much attention and servicing and is subject to various other disadvantages.

While both electric and pneumatic starting systems are considered more practical than other systems proposed for starting internal combustion engines, the pneumatic system provides the most satisfactory performance. The electric starting system, as used at present, is not entirely satisfactory from a military point of view. Such starters are very heavy and of relatively low power. Besides the weight of the electric starter itself, all airplanes so equipped must carry heavy battery equipment and be further reinforced by ground power plants weighing from 500 to 1,500 pounds each, or rely entirely upon the ground power plants for starting. Obviously, such airplane must remain close to the bases where such ground power plants are avialable, and in case of a forced landing remote from such a base the airplane must remain immobile until a ground power plant is available. In military operations, the starting of a number of aircraft presents a serious problem, especially in the case of the movement of an entire organization from one base to another. In extremely cool climates the power available from all battery sources is greatly reduced, thus further complicating the starting problem. In view of these disadvantages and those previously discussed, there are obvious advantages in the use of a light airborne system, and the pneumatic starter forming the subject matter of the present application is particularly adapted for use in such a system.

It is an important object of this invention to provide a starter device which is particularly adapted for use in starting a turbo-jet or turbo-propeller engine and capable of quickly accelerating the turbine to the high speed necessary to start the operation thereof.

Another object is to provide a starter device which is of the pneumatic type and which includes an air turbine driven by compressed air supplied from a suitable source, such as the compressor of a small easily started auxiliary power plant of the hot gas turbine type. By this arrangement, a relatively small, light-weight, self-powered, air-borne source of energy is utilized to great advantage and the necessity for providing a non-airborne source of power outside the airplane, such as an auxiliary ground power plant, is obviated. Consequently, engines of the turbo-jet or turbo-propeller types can be readily started at any time, regardless of the location of the airplanes in which they are installed. This is an extremely important advantage since by this means military airplanes of these types can be quickly propelled into the air from any field of operation and for this reason it is unnecessary that the airplanes return to the base from which their flight is started. In addition, a pneumatic starter which derives power from an airborne auxiliary power plant of the hot gas turbo-compressor type is capable of effecting an unlimited number of starts since it is not dependent upon storage batteries or other similar sources of stored-up energy.

Another object is to provide an engine starter for aircraft which is extremely light in weight and occupies very little space in the aircraft, and one which is highly efficient and dependable in operation and requires little attention on the part of the airplane crew except to operate the controls thereof.

Another object of the invention is to provide a small, compact starter device of the type indicated capable of delivering high torque and one which may be conveniently installed on and removed from the aircraft engine.

A further object is to provide a starter

unit in which is incorporated a releasable driving connection between the output shaft of the starter and the engine, this connection being of a centrifugally-actuated type and functioning to automatically disengage the starter shaft from the turbo-jet shaft when the latter attains a speed capable of sustaining full continuous operation of the engine being started.

A still further object is to provide a pneumatic starter unit which includes a planetary speed reduction gearing and a friction clutch in its power transmitting mechanism, said clutch being adapted to slip upon the occurrence of unusual drag or resistance to the free rotation of the starter output shaft, such as might be caused by an abnormal or overload condition.

Another object is to provide a pneumatic starter to which may, if desired, be operated by a mobile ground power plant capable of being moved into proximity with an airplane located on a field and readily connected to the engine or engines thereof to start the same. In this respect, the present invention also contemplates a starter system in which a source of compressed air, such as a small hot gas turbo-compressor, is carried by a mobile ground power plant which can be readily moved into position adjacent an airplane to supply compressed air to a pneumatic starter mounted on and adapted, when operated, to start the airplane engine. It is also proposed to provide a quick disconnect means for attaching the pneumatic starter device to an aircraft engine so that after the engine has been started, the device can be readily detached therefrom and retained with the ground power plant. Such an arrangement wherein the starter device is retained on the ground has the advantage of conserving weight in the airplane and, in the case of a high speed military airplane, the exclusion of even this small weight may be extremely important. The present invention further contemplates the provision of a ground power plant in which the turbo-compressor is capable of supplying sufficient compressed air to the starter devices of several engines, as is the case where the aircraft is of the multi-engine type.

The present invention is directed to the starter device *per se* and reference made above, and subsequently, to preferred sources of compressed air for operating the device, and to the quick disconnect means therefor is merely for the purpose of illustrating the adaptability of the starter in connection with aircraft engines.

In the accompanying drawings:

Fig. 1 is a longitudinal sectional view through an engine starter device constructed in accordance with the present invention;

Fig. 2 is an end view of the turbine end of the device shown in Fig. 1;

Fig. 3 is an end view of the power output end of the device;

Fig. 4 is a cross-sectional view, taken on line 4—4 of Fig. 1;

Fig. 5 is a cross-sectional view, taken on line 5—5 of Fig. 1;

Fig. 6 is a cross-sectional view, taken on line 6—6 of Fig. 1;

Fig. 7 is a cross-sectional view, taken on line 7—7 of Fig. 1; and

Fig. 8 is a perspective view of a pair of turbo-jet aircraft engines, illustrating the present pneumatic starter applied to use in starting the engines and connected to be operated by compressed air derived from an airborne auxiliary power plant.

The present pneumatic starter device, while capable of starting engines of various types, is herein illustrated and described, by way of example, as arranged to start one or more aircraft engines of the turbo-jet type. Referring to Fig. 8, the turbine engines 15 and 16 are adapted to be started by means of identical pneumatic starter devices 17 and 18 which are connected to the engines, by means to be later described, and which are operated by compressed air supplied from a suitable source, such as the auxiliary power plant illustrated generally at 20 in Fig. 8 and described in more detail hereinafter. The engine starter together with its source of compressed air, may be completely airborne and will be first described in this connection, although the starter power plant may be operated by a mobile ground servicing unit, to be referred to later in the specification.

Referring now to Figs. 1 to 7 of the drawings, the engine starter device 17 includes a housing 21 which is composed of an inner section 22, an intermediate section 23 and an outer section 24, the section 22 enclosing a coupling means 25, the section enclosing a planetary speed reduction and power transmission means 26, and the section 24 providing the housing of an air turbine 27. The inner and intermediate sections have matching peripheral flanges which are detachably secured together by means of bolts 28. In a similar manner, the outer section 24 is detachably connected to the intermediate section 23 by means of bolts 29.

The intermediate housing section 23 is provided with an inner, annular flange 30 to which is secured, by screws 31, a cup-like holder 32 which receives the outer race of a ball bearing 33, an annular seal member 34 also being retained in place against the flange 30 by the screws 31. The

inner housing section 22 is also provided with an internal flange 35 which defines an axial opening in which a ball bearing 36 is disposed. An internal driving element 40 is composed of axially aligned components 41 and 42 which are secured together by studs 43 and nuts 44. The ends of the components 41 and 42 are reduced in diameter to adapt them to be received in the inner races of the respective ball bearings 33 and 36. Held within the end of the component 42 of the driving element 40 by a transverse pin 45 is one element 46 of the coupling means 25.

The forward end of the component 41 of the driving element 40 is provided with a bore in which is held a pair of ball bearings 48 and 49 which are retained in axially spaced relationship by a tubular spacer 50. Rotatable within the ball bearings 48 and 49 is a turbine wheel shaft 52 which is provided with a pinion gear 53 at its inner end, this gear being hereinafter referred to as the sun gear of a planetary gear system to be later described. The forward end of the shaft 52 is disposed within the turbine housing section 24 and mounted on this end of the shaft is a turbine wheel 55 having curved, generally radially extending blades 56 on the forward face of the wheel adjacent its periphery. As shown in Fig. 1, the turbine wheel 55 is keyed to the shaft 52 as indicated at 57 and is held axially in place by nut means 58 screwed on to the forward threaded end of the shaft, a spacer ring 59 being disposed between the rearward side of the wheel and the ball bearing 48.

As shown in Figs. 1 and 2, the forward housing section 24 has a central annular portion 62 which is joined to a circular wall 63. Extending radially outward from the portion 62 is an inclined circular wall 64 which is provided at its periphery with an annular flange-like portion 65. Provided in the portion 65 is a plurality of substantially tangential nozzles having nozzle openings 66 which, as shown in Fig. 4, are defined in part by inclined partitions or vanes 67. The walls 62, 63, 64, 65 of the turbine housing section 24, together with the forward annular wall of the intermediate housing section 23, define a helical or scroll passage 68, a tangential tubular portion 69 providing an air inlet communicating with the passage. By this construction, compressed air introduced into the scroll passage 68 by way of the inlet 69 passes through the inclined nozzle openings 66 and impinges against the blades 56 of the turbine wheel 55 to rotate the latter, the air, after performing its work, discharging through an axial passage 70, defined by the annular portion 62, and through a screen 71 in this passage. The turbine unit thus is of the substantially radially inward, axial discharge flow type, this form of turbine having been found to be highly efficient in operation and especially suitable for the present starter device.

The outer component 41 of the driving element 40 has a flange 73 provided with three bores in which ball bearings 74 are disposed and retained by rings 75. Planetary gear shafts 76 have one of their ends rotatably disposed in the ball bearings 74 and their opposite ends rotatable in roller bearings 77 positioned in apertures 78 of the inner component 42. The shafts 76 are provided with integral gears 79 and flanges 80. Carried by the shafts 76 between the flanges 80 and the inner races of the ball bearings 74 are larger gears 81, the teeth of which mesh with the teeth of the sun gear 53. Each pair of gears 81 and 79 constitutes a compound planetary gear since each is carried by one of the shafts 76 and rotatable therewith.

As thus far described, rotation of the turbine wheel shaft 52 and sun gear 53 will merely impart rotation to the gears 81, shafts 76 and gears 79. However, in order to transmit power from the wheel shaft 52 to the driving element 40 and the element 46 of the coupling means 25, preferably at a reduced rate of speed, means are embodied in the starter device for causing the shafts 76 to revolve in an orbit around the sun gear 53. This means consists of a ring gear 85 having internal gear teeth with which the teeth of the planetary gears 79 mesh. The orbit gear 85 is rotatable in a circular opening 86 in the intermediate housing section 23 and has an annular flange 87, a side of which is disposed against a plurality of friction discs 88 fast within the section.

A friction clutch 90 is disposed within the housing section 22 and includes a pair of rings 91 and 92, the latter being disposed in an annular recess 93 of the section. The rings 91 and 92 are joined by pins 94 and the clutch 90 is held against rotation by lugs 95 on the ring 91 (Fig. 1) engageable in slots 96 in the inner face of the housing section 23 (Fig. 6). The ring 91 is provided with a plurality of friction discs 97 which normally engage against the inner face of the flange 87 of the orbit gear 85 as shown in Fig. 1, the ring 91 being urged in a direction to maintain such engagement by means of compression springs 98, surrounding the connecting pins 94 with their ends engaging the rings 91 and 92. It is thus apparent that normally the ring gear 85 is held stationary so that during rotation of the sun gear 53 the compound planetary gear 81, 79 is caused to travel around the ring gear to thus

transmit power to the driving element 40 and coupling element 46 at a speed of rotation which is considerably less than that of the turbine wheel shaft 52. It is also to be noted that when the coupling element 46 is subjected to a load in excess of a predetermined value, sufficient torque may be applied by the shaft 52 through the compound planetary gears 81, 79 to the ring gear 85 to cause the latter to completely or partially overcome frictional resistance of the discs 88 and 97 to produce slippage. When this condition prevails, the compound planetary gears 81, 79 will merely rotate on their own axes and may or may not revolve about the sun gear 53, depending upon the degree of slippage occurring between the orbit gear 85 and the friction discs 88, 97.

The coupling device 25 includes, in addition to the element 46, an outer element 100 which is disposed coaxially with the element 46, the element 100 being hereinafter referred to as a drive shaft since it is adapted for connection with the engine to be started. The drive shaft 100 is provided with an intermediate portion 101 which is rotatable in a bearing plate 102 secured to the end of the inner housing section 22, a sealing ring 103 being employed to prevent escape of lubricant from the housing 21. The drive shaft 100 has a reduced outer end 104 which projects from the housing section 22 and which has a splined periphery (Figs. 1 and 3). The inner end 105 of the drive shaft 100 is annular and surrounds the inner end 106 of the coupling element 46. The end 105 is provided with a pair of bosses 110 having bearing holes in which weighted pawls 111 are pivotally mounted (Figs. 1 and 7). The pawls 111 have pointed ends 112 which are adapted to be disposed in recesses 113 formed on the periphery of the inner end 106 of the element 46 as shown in Fig. 7, the recesses providing shoulders 114. The pawls 111 normally are retained in this position by means of leaf springs 116 which have one of their ends secured within the end 105 and their free ends engaging the pawls.

The entire starter device 117 is adapted to be detachably secured to an end of a turbo-jet or turbo-propeller engine 15, the inner housing section 22 being provided with a peripheral flange 118 having holes 119 through which bolts 120 can be inserted and screwed into holes in the end of the engine 15. The fluted end 104 is adapted to enter a splined end of a shaft 121 of the engine 15 to provide a positive driving connection therewith so that when the drive shaft is driven by the turbine wheel 55 of the shaft of the engine is likewise rotated. While the starter device 17 is herein illustrated as attached to the engine 15 by the bolts 120, it may be detachably connected thereto by means of a suitable quick disconnect means, such means providing for quick removal of the starter device from the engine for inspection, repair, etc. In some airplanes, particularly those of the high speed military types, it may be highly desirable to conserve even the relatively small weight of the starter device. In this case, the starter device may be attached to the engine by the quick-disconnect means only until the latter is started and quickly disconnected therefrom after continuous operation of the engine is assured, the device then being removed from the airplane and retained on the ground. In other words, the starter device may be either airborne or incorporated with a mobile ground servicing power plant. As previously pointed out, the quick-disconnect means forms no part of the present invention and for this reason is not herein disclosed in detail.

It has been stated that the starter devices 17 and 18 are adapted to be operated by compressed air introduced into the scroll housing section 24 by way of the inlet passage 69, the motive air then being directed substantially radially through the inclined nozzles 66 where it impinges against the blades 56 of the turbine wheel 55 to rotate the latter at a high rate of speed, the air then discharging from the starter device in an axial direction through the exhaust opening 70. Rotation of the turbine wheel 55 and its shaft 52 and sun gear 53, causes rotation of the compound planetary gears 81, 79. As rotation of the coupling element 46 is started, the shoulders 114 thereof, acting against the ends 112 of the pawls 111, transmit torque to the drive shaft 100 and thence to the engine shaft 121 to rotate the same.

The strength of the clutch springs 98 is so calculated that complete fixation of the orbit gear 85 occurs immediately in the engine starting cycle and thus during the starting operation full power is transmitted to the engine and high speed of the latter is rapidly attained, that is, the speed of the engine is increased to a point at which the jet engine can satisfactorily accelerate itself to operating speed. When this latter speed of the engine is attained, centrifugal force causes the pawls to pivot outwardly, as indicated by the broken lines in Fig. 7, against the action of the leaf spring 116. Consequently, the transmission of power from the turbine wheel 55 to the engine shaft 121 is automatically disrupted and, since the starter then performs no further work, it can be stopped.

As previously mentioned, the pneumatic

starter device is adapted to be operated by compressed air derived from any suitable source. It has been determined, however, that a small light weight auxiliary power plant of the type illustrated at 20 in Fig. 8 which may be started by a relatively small electric motor or other suitable means is especially suitable for supplying compressed air to the pneumatic starter constituting the present invention. The auxiliary power unit 20 includes a hot gas turbine plant 125 which drives an air compressor unit 126 disposed in alignment with the unit 125. Air is drawn into the multi-stage air compressor unit through an inlet 127, the compressed air then passing through combustion chambers 128 wherein the enthalpy of the compressed air is increased by the combustion of fuel therein, the hot gas then passing through ducts 129 to enter the turbine scroll housing 130 and being directed through nozzles against the blades of a turbine wheel which is operatively connected to drive the compressor unit. The flow of air through the cycle referred to above is indicated by full line arrows in Fig. 8.

A portion of the air compressed in the unit 126 is bled therefrom at points 133 and, when the power unit 20 is installed in an airplane, this air may be diverted to the airplane pneumatic power system or to other pneumatically operated mechanisms through branch tubes 134 and a duct 135. In the pneumatic starter system disclosed in Fig. 8, a portion of the compressed air flowing through the duct 135 is adapted to be diverted to either or both of the two engine starter devices 17 and 18 by way of respective ducts 137 and 138 connected between the duct 135 and the inlet tubes 69 of the starter devices. Valves 140 and 141 are disposed in the respective ducts 137 and 138 and adapted to control the flow of the compressed air to the pneumatic starters. When the valves 140 and 141 are opened, the flow of air bled from the compressor 126, through the starters, is as indicated by the broken arrows in Fig. 8.

As thus far described, the entire starter system which includes the starters 17 and 18, the auxiliary power plant 20 and the connecting air ducts, is adapted for installation in an aircraft and, where wholly feasible, such an airborne arrangement is obviously preferable. By installing the system in the aircraft so that it is a component thereof, many advantages are attained. For example, a major advantage resides in the fact that the starter system is always available for use so that the aircraft engines can be started at any time, regardless of the location of the craft, and it is unnecessary to return the airplane to the base from where it flew in order that its engines may be subsequently re-started. Thus, by this arrangement it is possible to quickly start the individual engines of a group of airplanes without relying upon an outside source of power for operating the starters thereof, and the take-off of the group of airplanes is greatly expedited. As will be apparent, this is of extreme importance especially when combat airplanes must leave the field quickly to intercept enemy craft. Should a forced landing become necessary, the engine or engines of the airplane may be subsequently started at the location where the airplane lands, it being unnecessary to await the arrival of a mobile ground power plant for the purpose.

In most airplanes, the installation of the instant starter devices and auxiliary power plant is wholly practical since both units are compact and extremely light in weight. In this respect, it is pointed out that the weight of a single pneumatic starter of the type disclosed herein and having a horsepower rating of 35 is approximately 15 pounds and that of the auxiliary power plant is approximately 68 pounds so that the major components of the airborne system weigh approximately 83 pounds. Compared to, for example, an electric starter system, this represents a material saving in weight since an electric starter of comparable horsepower weighs approximately 45 pounds and storage batteries for operating the starter weigh approximately 160 pounds, the total weight of the major components of an airborne electric system thus being approximately 205 pounds or substantially 2½ times that of the present pneumatic system. It is thus seen that the pneumatic starter system, illustrated herein by way of example, at least partially solves the problem of weight and provides a highly efficient and practical means for effecting an unlimited number of engine-starting operations without assistance from an outside source of power such as a ground power plant. Moreover, the auxiliary power plant which supplies compressed air for operating the starter unit or starter units may also serve various other functions such as providing (1) a pneumatic or direct mechanical drive for an aircraft alternator, (2) providing hot gas for wing de-icing purposes, (3) providing compressed air for operating an air-cycle refrigerating unit for conditioning aircraft cabins on the ground, and (4) providing, with proper heat exchangers, means for heating aircraft engines, cabins, etc. It is thus seen that by the system described above a portion of the available compressed air from the auxiliary power

plant may be utilized for operating the engine starter devices. In other words, when the auxiliary power plant is installed in the airplane, an adequate supply of compressed air is always available.

While the engine starter has been described as embodied in a system of an airborne type, it may also be advantageously employed in connection with a system in which the auxiliary power plant is not installed in the airplane but rather is a mobile ground power plant. As previously indicated, in the case of high speed turbo-jet and turbo-propeller airplanes, the overall weight of the craft may be extremely critical and it may be highly desirable to omit such accessories as the auxiliary power plant, and even the starter devices, from the airplane. In other words, it may be deemed more expedient to sacrifice the convenience and other desirabilities of having the starter system installed in the airplane for the saving in weight, even though the present system is of considerably lighter weight than other systems heretofore proposed. In such case, the auxiliary power plant is adapted to be mounted on a mobile servicing cart which can be readily propelled to a location adjacent the turbine engine to be started, compressed air then being forced through a flexible, reinforced hose to the inlet of the air turbine of the starter device. A servicing cart of this type may also be employed for preheating the airplane engine and the cabin or cockpit of the craft. Such a servicing unit is comparatively light in weight and therefore is more conveniently moved into operative position than similar units employed in conjunction with electric starter devices and employing electric generators driven by large, heavy, internal-combustion engines.

What we claim is:—

1. A starter device for a high speed internal combustion engine having a shaft, comprising: a housing adapted to be detachably connected to the engine; a drive shaft rotatably supported in said housing and adapted to be operatively connected to the shaft of the engine; a turbine in said housing having an air driven wheel; and transmission means interconnecting said wheel and said drive shaft, said transmission being adapted to partially or completely interrupt the transmission of power to the drive shaft in response to the occurrence of an overload condition.

2. A starter device according to Claim 1, having a disengageable coupling means between said drive shaft and the shaft of the engine.

3. A starter device according to Claim 1, wherein said transmission means includes a sun gear operatively connected to said turbine wheel and rotatable therewith; an orbit gear rotatable in said housing and arranged concentrically with said sun gear; a carrier rotatable in said housing; a compound planet gear on said carrier and in mesh with said sun gear and said orbit gear and revolvable in an orbit therebetween; a coupling means between said carrier and said drive shaft; and friction means normally operative to resist rotation of said orbit gear so as to cause said planet gear to rotate said carrier and said drive shaft, said friction means being adapted to yield in response to a load of predetermined magnitude applied against said drive shaft so as to allow rotation of said orbit gear.

4. A starter device according to Claim 1 or 2, having a friction clutch incorporated in said power transmission means, said clutch being adapted to slip upon occurrence of a load imposed on said drive shaft in excess of a predetermined value.

5. A starter device according to Claim 2, characterized in that said coupling means normally provides a positive driving connection but is adapted to become disengaged from the shaft of the engine in response to speed of the engine shaft in excess of a predetermined value.

6. A starter device according to Claim 2 or 5, wherein said coupling means is centrifugally controlled and includes a first member on said drive shaft, a second member connectible to the engine shaft, and at least one centrifugally operated element movable on one of said members and engageable with the other of said members and engageable with the other of said members to effect a driving connection, said element being adapted to be moved in a position to disengage said other member in response to centrifugal force in excess of a predetermined value.

7. A starter device according to Claim 6, wherein said element comprises a pawl pivotally connected to one of said members and engageable with a shoulder on the other of said members.

8. A starter device according to Claim 7, in which said coupling means includes resilient means engageable with said pawl and operative to yieldingly maintain the same in engagement with said shoulder.

9. A starter device according to any one of the foregoing claims, in which said turbine is of the radially inward, axially discharge flow type.

10. A starter device according to Claim 9, wherein said turbine has a wheel provided with substantially radial blades, and has a plurality of nozzles disposed substantially tangential to said wheel.

11. A starter device for use in starting a high speed internal-combustion engine,

constructed and adapted to operate substantially as herein described with reference to Figs. 1 to 8 of the accompanying drawings.

Dated this 25th day of November, 1949.

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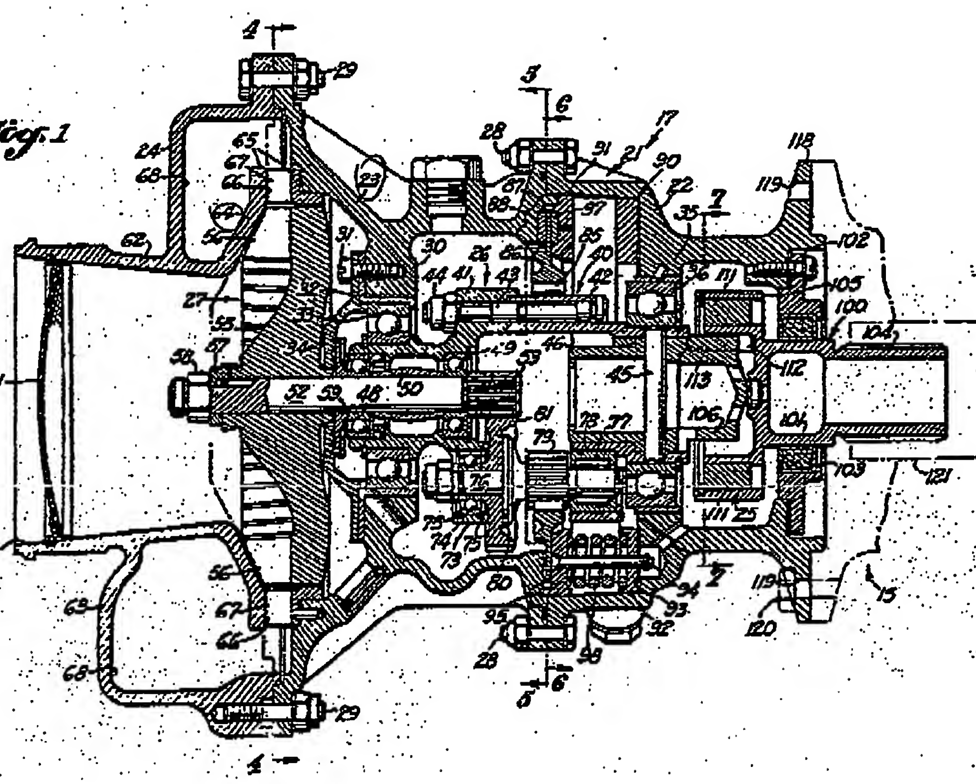
Fig. 1



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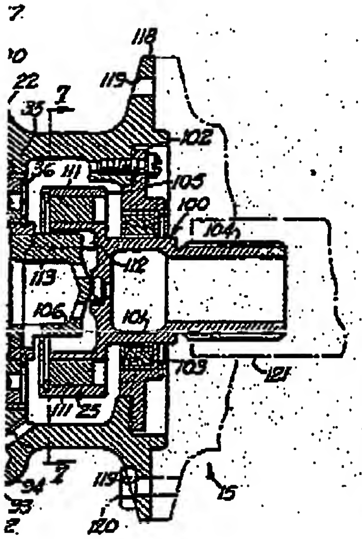


Fig. 2

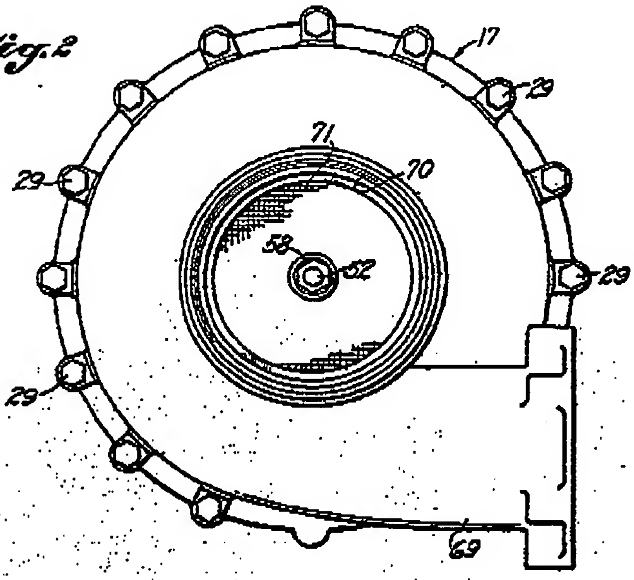
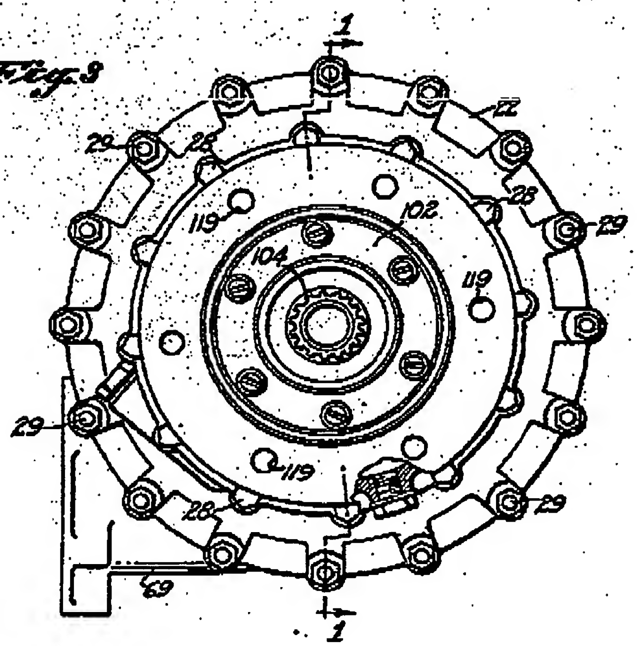


Fig. 3



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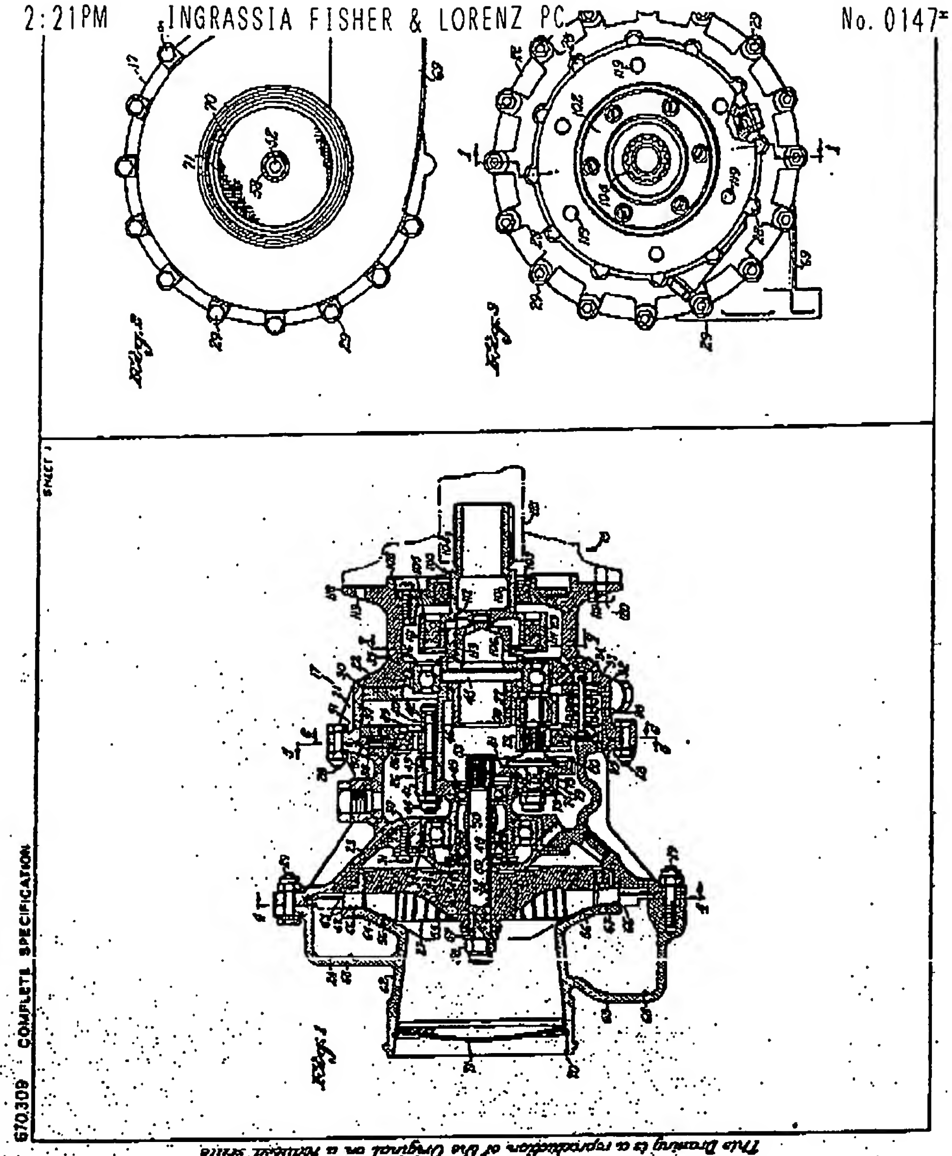
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Fig. 4

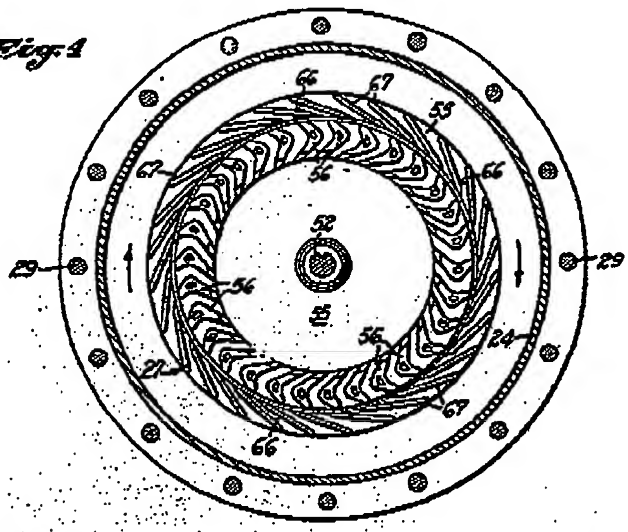


Fig. 5

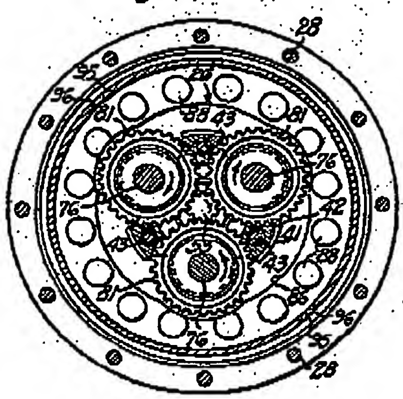
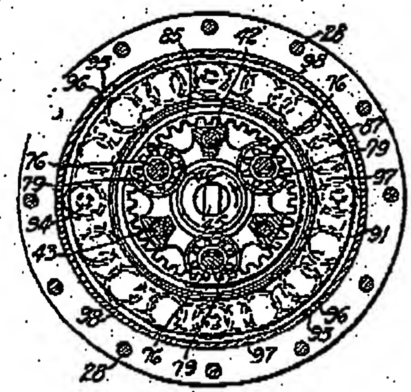


Fig. 6



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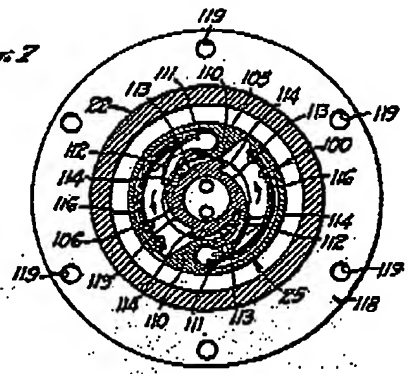
SHEET 4

Fig. 7



6

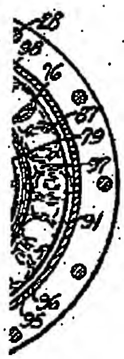
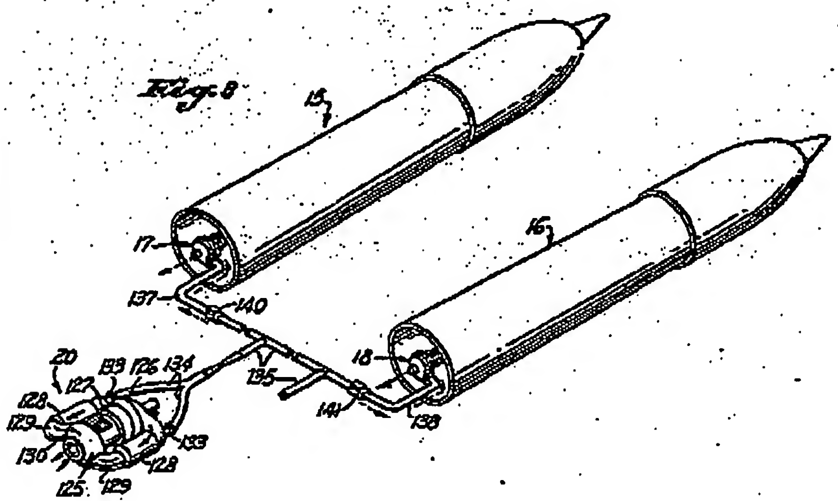
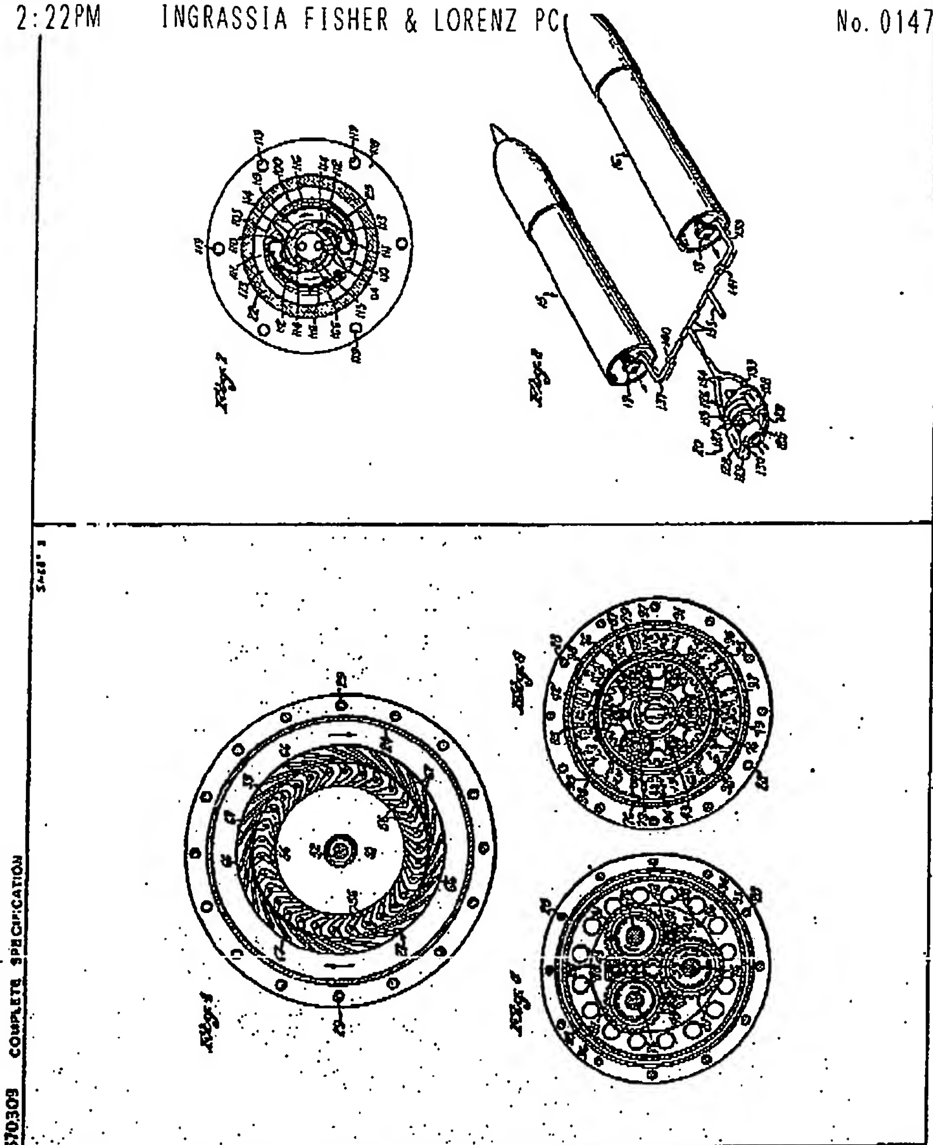


Fig. 8



H.M.S.O. (M.F.P.)



This Drawing is a reproduction of the Original on a reduced scale